Evaluation of optical parameters for tungsten from polarized thermal radiation

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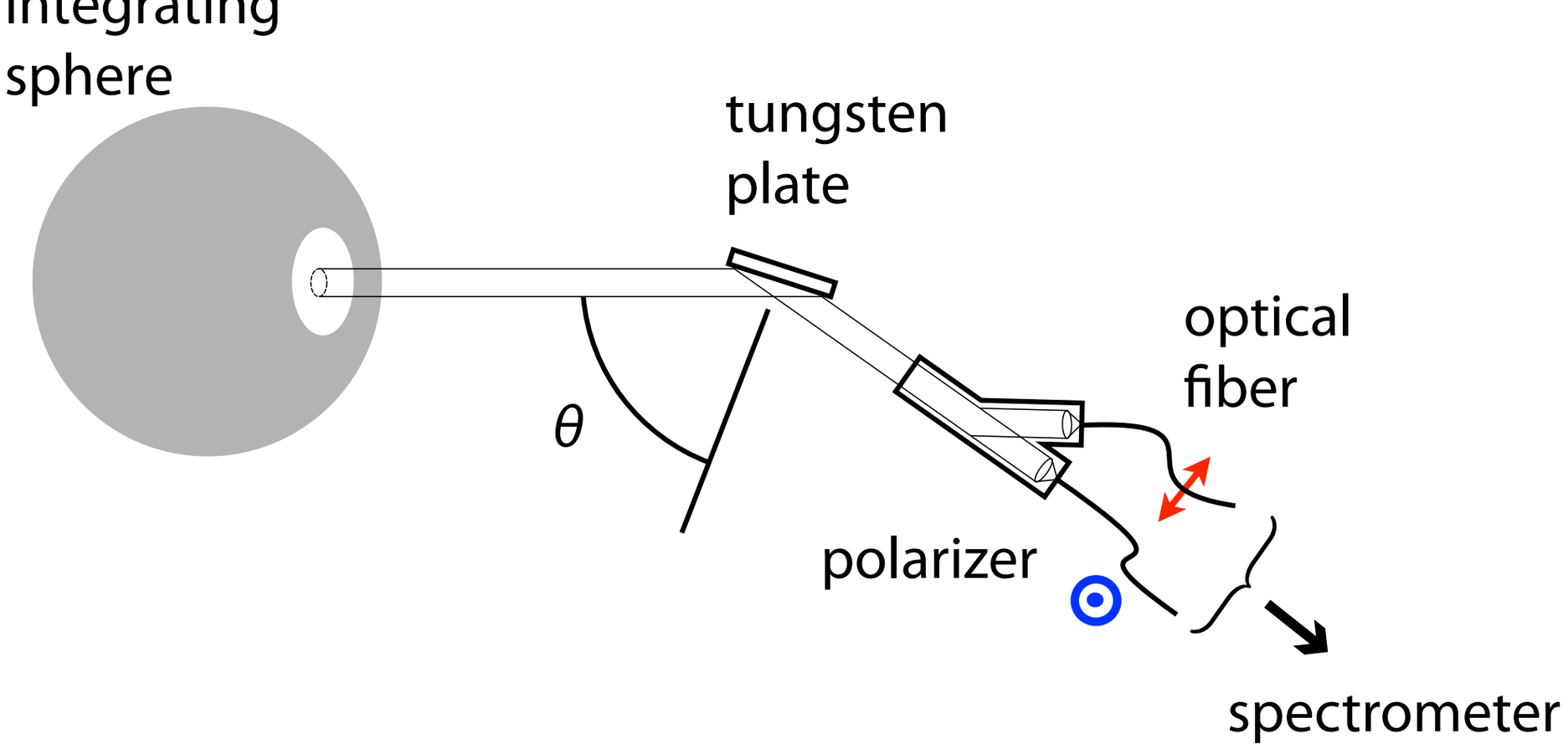
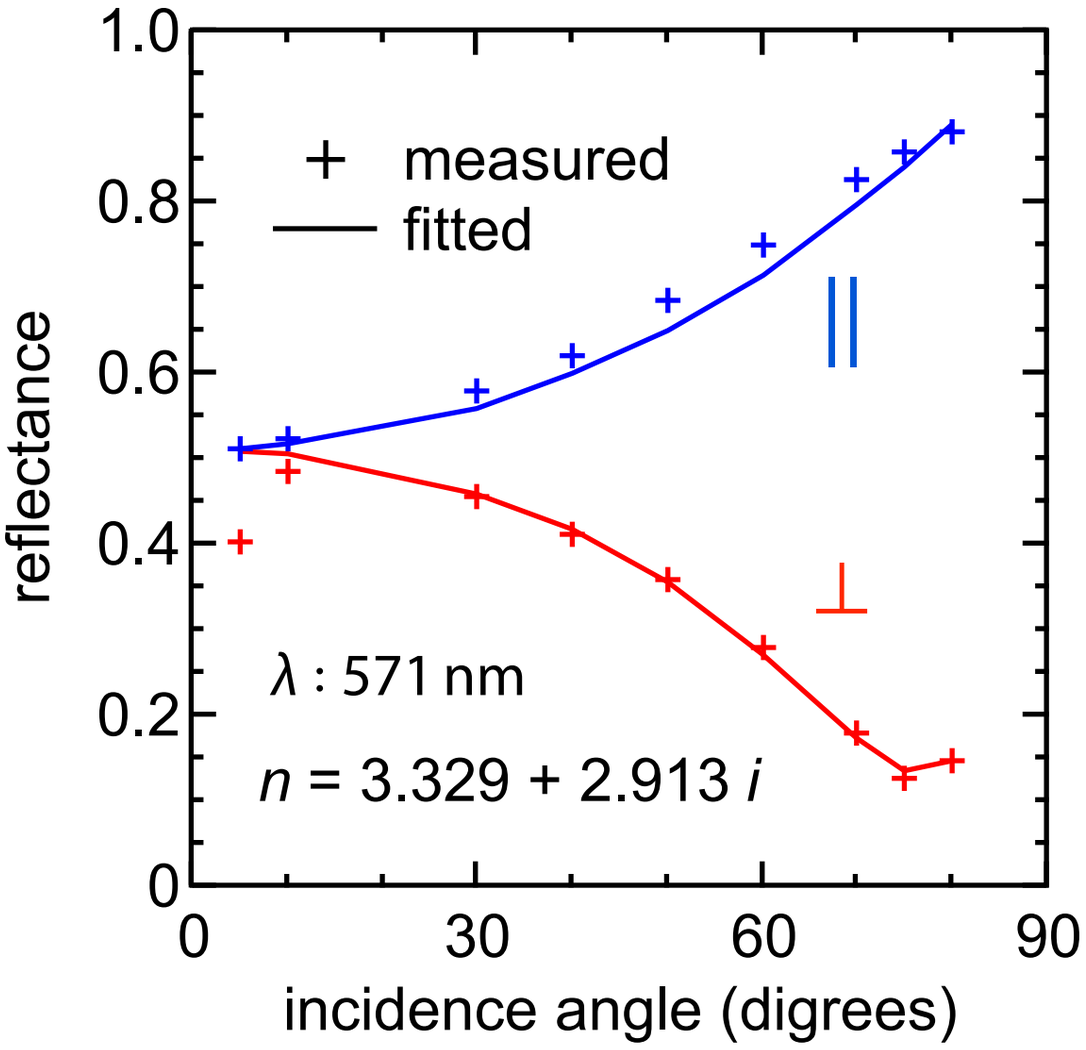
- Kirchhoff's law stipulates a relationship between reflectance and emissivity
- reflectance of dielectric material has polarization dependence, so emissivity should also

reflectance measurement

optical constants are determined
from dependence of reflected light
on polarization





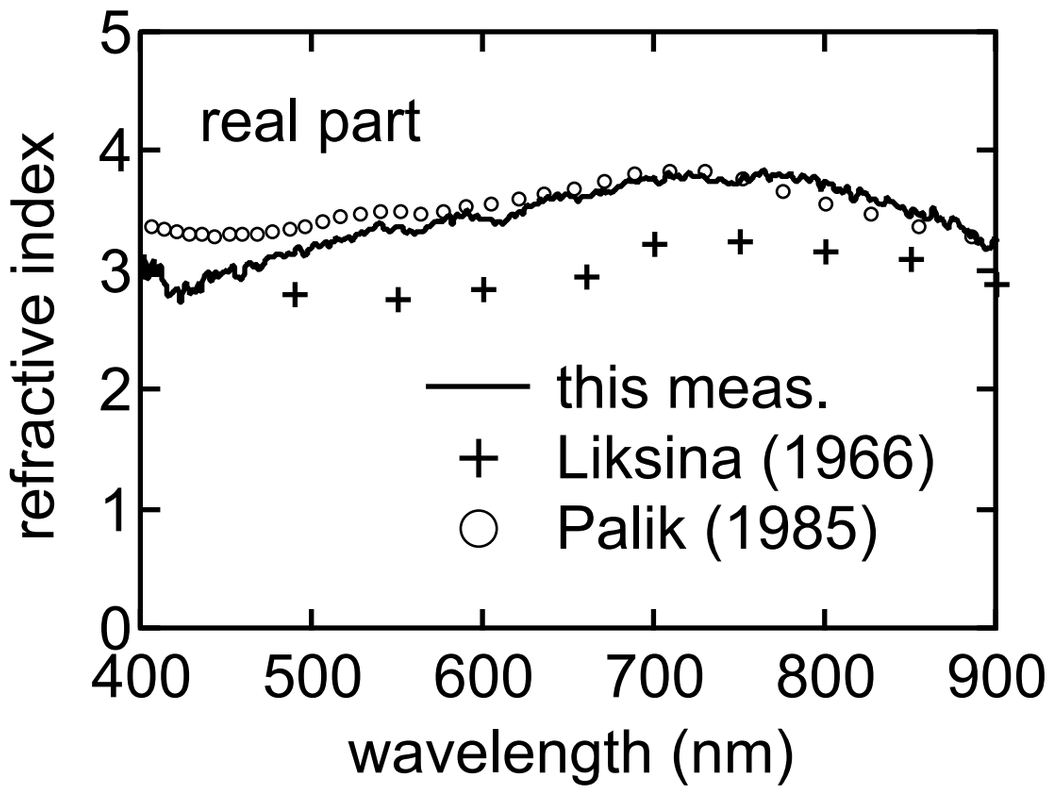
Fresnel equation

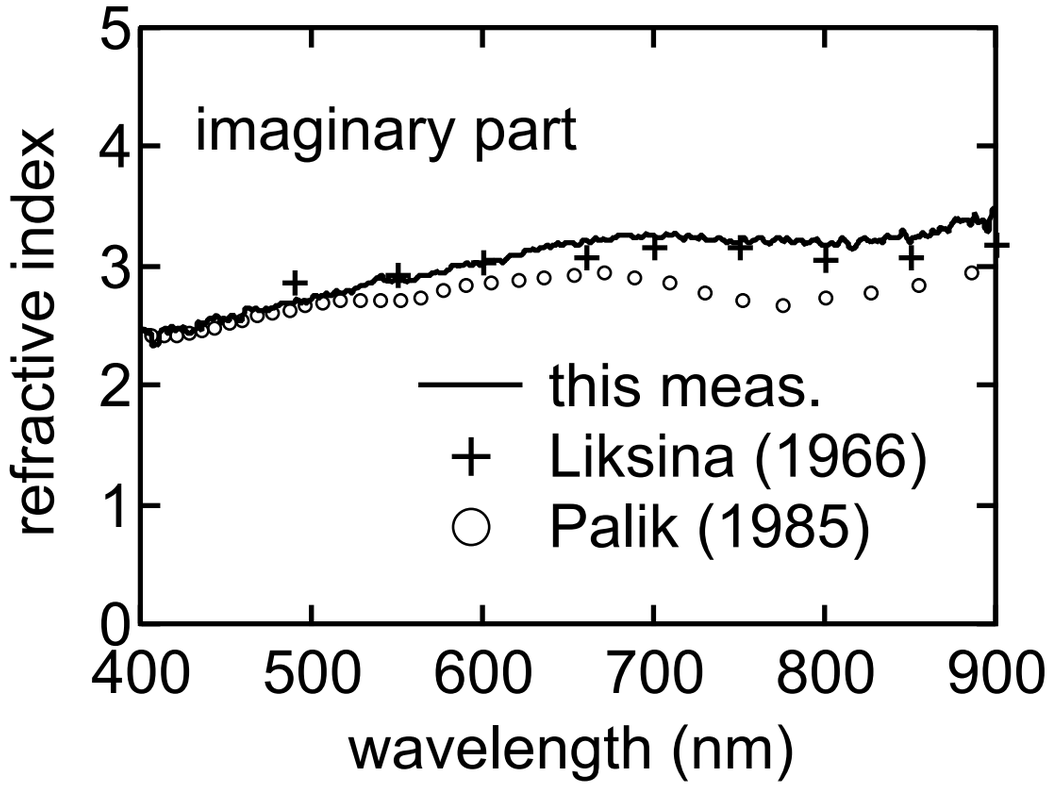
$$R_{\parallel} = \left| \frac{\hat{n}^2 \cos\theta - \sqrt{\hat{n}^2 - \sin^2\theta}}{\hat{n}^2 \cos\theta + \sqrt{\hat{n}^2 - \sin^2\theta}} \right|^2$$

$$R_{\perp} = \left| \frac{\cos\theta - \sqrt{\hat{n}^2 - \sin^2\theta}}{\cos\theta + \sqrt{\hat{n}^2 - \sin^2\theta}} \right|^2$$

$$\hat{n} = n + i\kappa$$

refractive index for tungsten





refractive index may depend on temperature

same method is difficult to use for high temperature case

can thermal radiation be instead used?

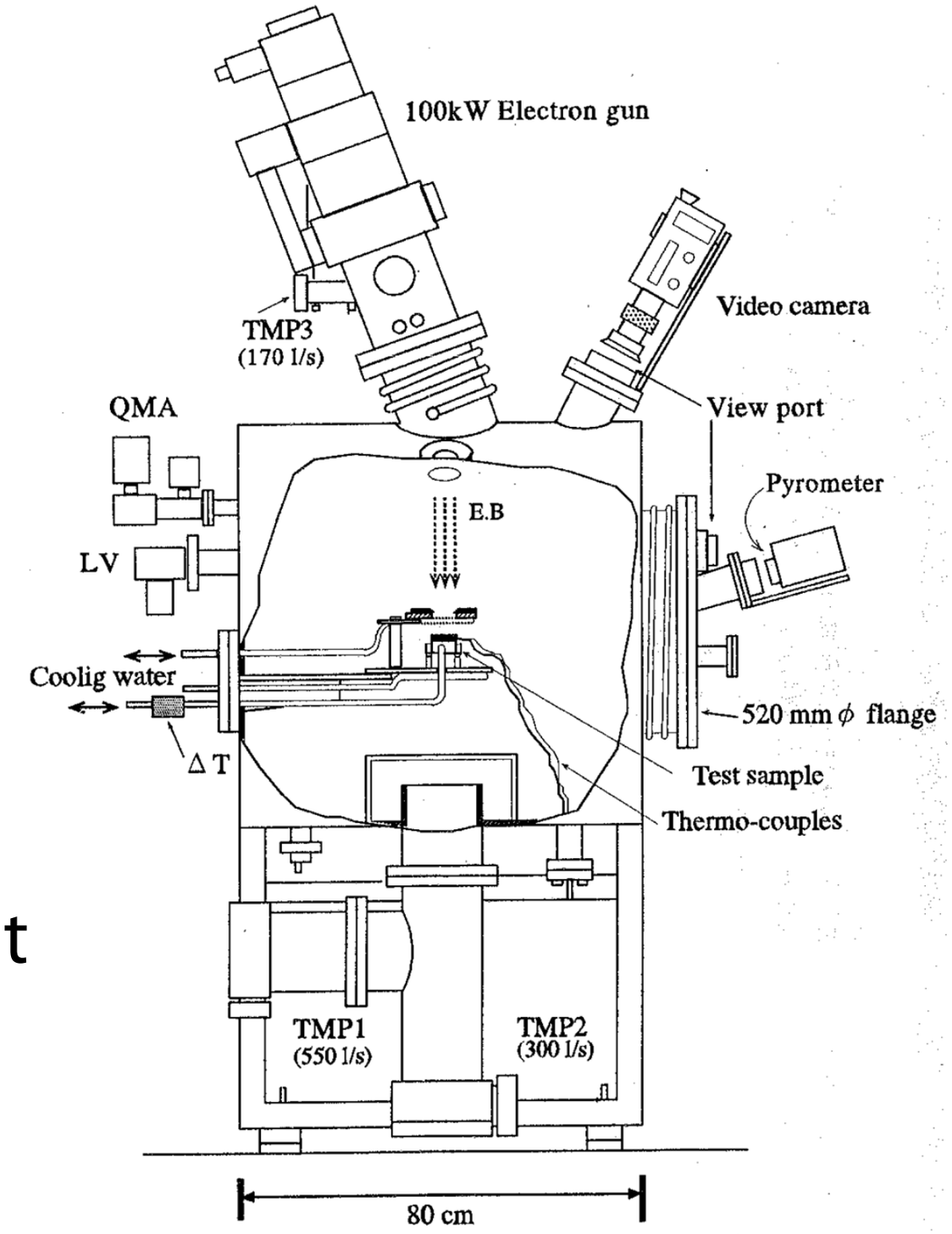
reflectance = 1 - emissivity

$$\left(\text{emissivity} = \frac{\text{thermal rad.}}{\text{black-body}}\right)$$

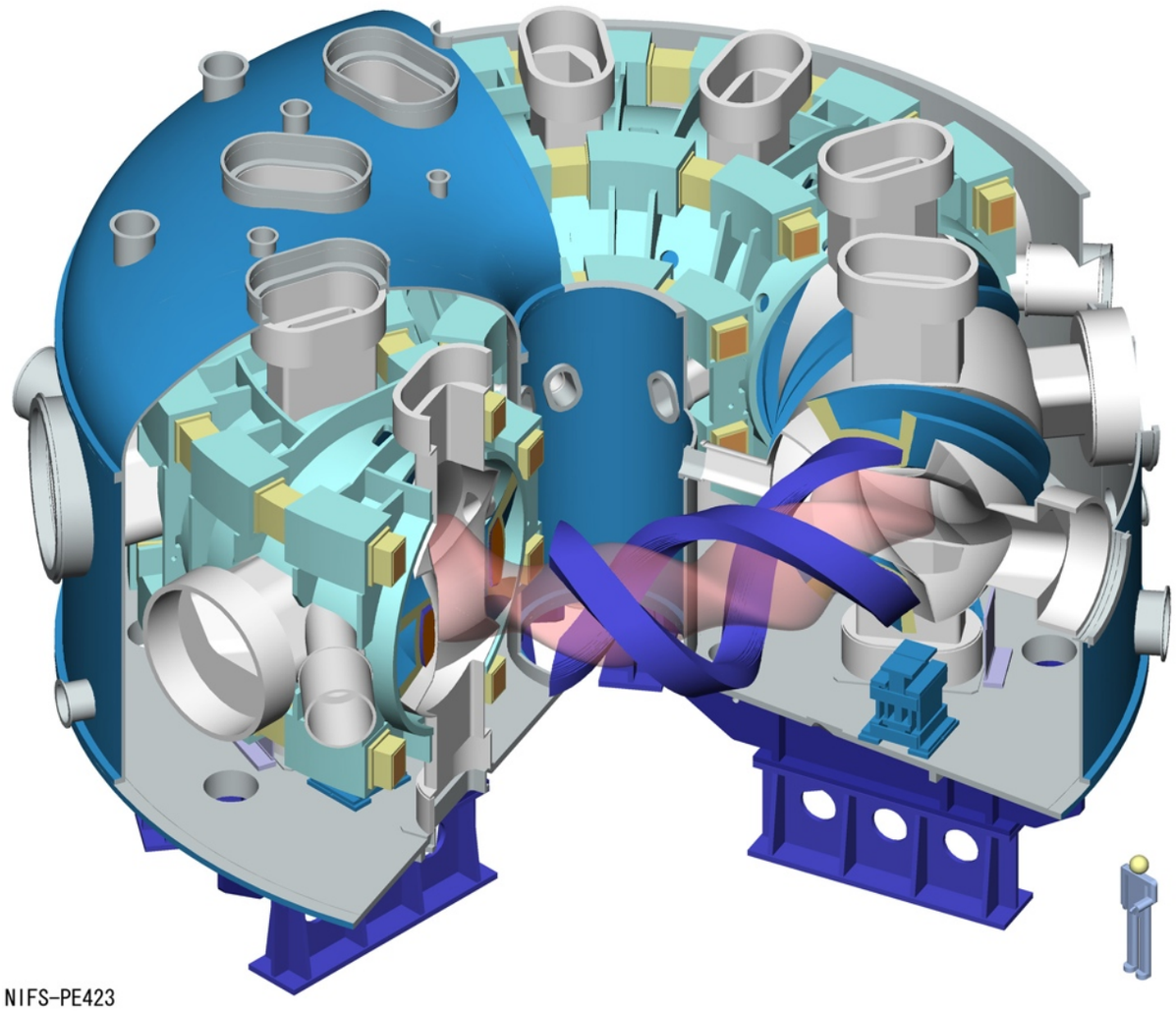
ACT (Active Cooling Teststand)

voltage	30 kV
current	3.3 A (max)
irradiated area	1-400 cm^2
heat load on target	0-100 MW/m^2

used for material development for divertor plates in fusion device



LHD (Large Helical Device)



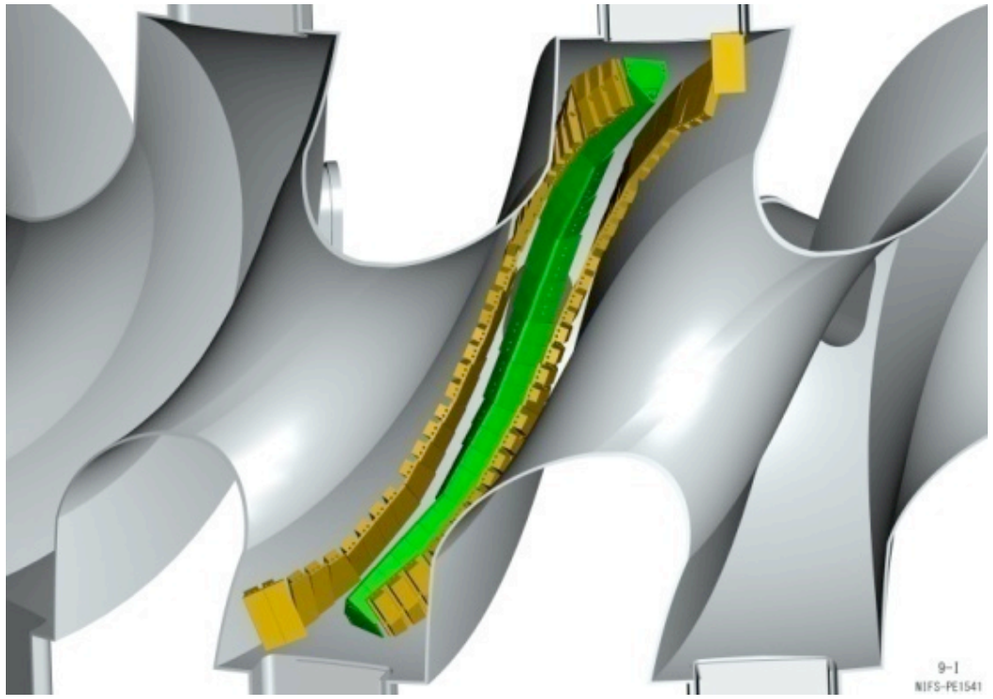
specifications

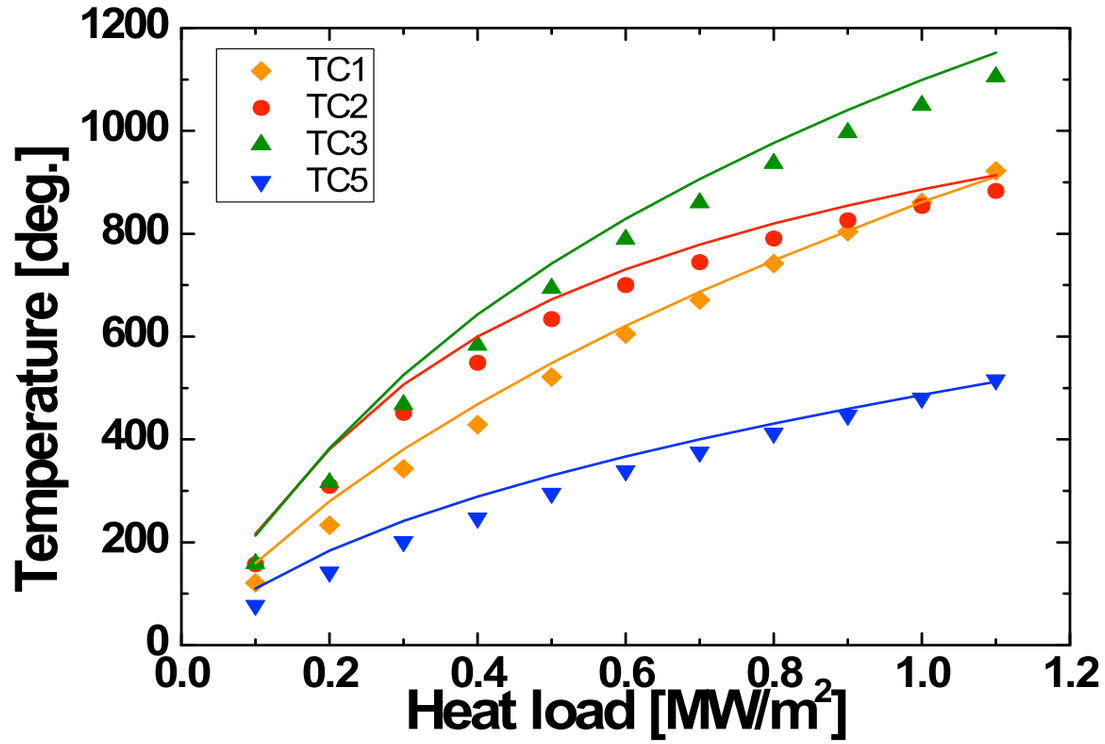
major radius	3.5 - 4.2 m
minor radius	0.6 m (avg.)
magnetic field	< 3 T
plasma volume	~ 30 m^3

achievements

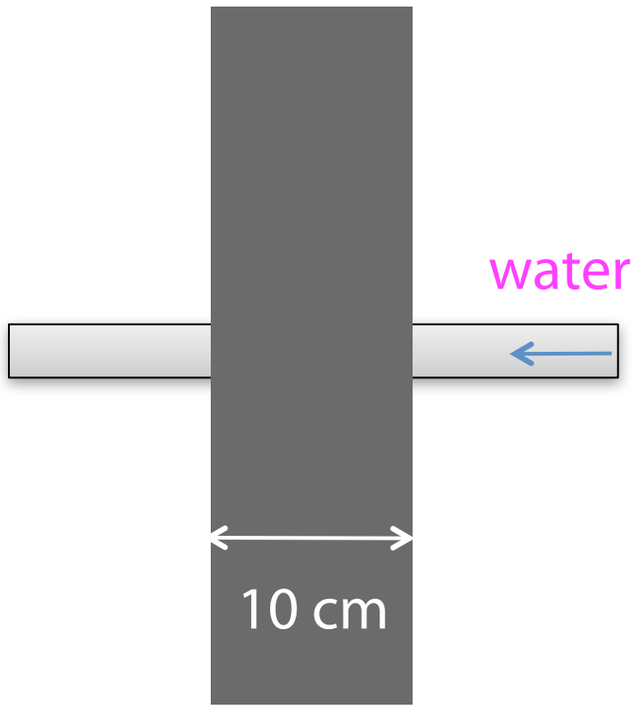
P_{in}	=	20 MW
T_e	=	15 keV
T_i	=	13 keV
n_e	=	1×10^{21} m^{-3}

temperature distribution analysis in material

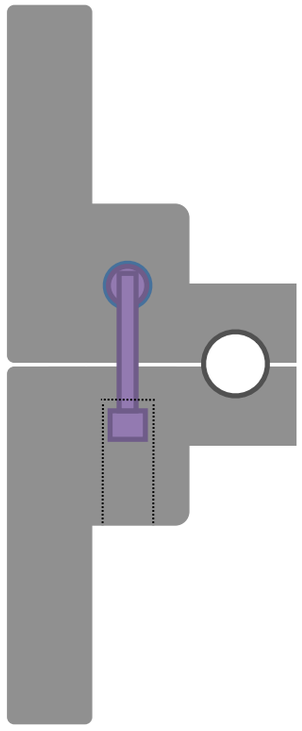


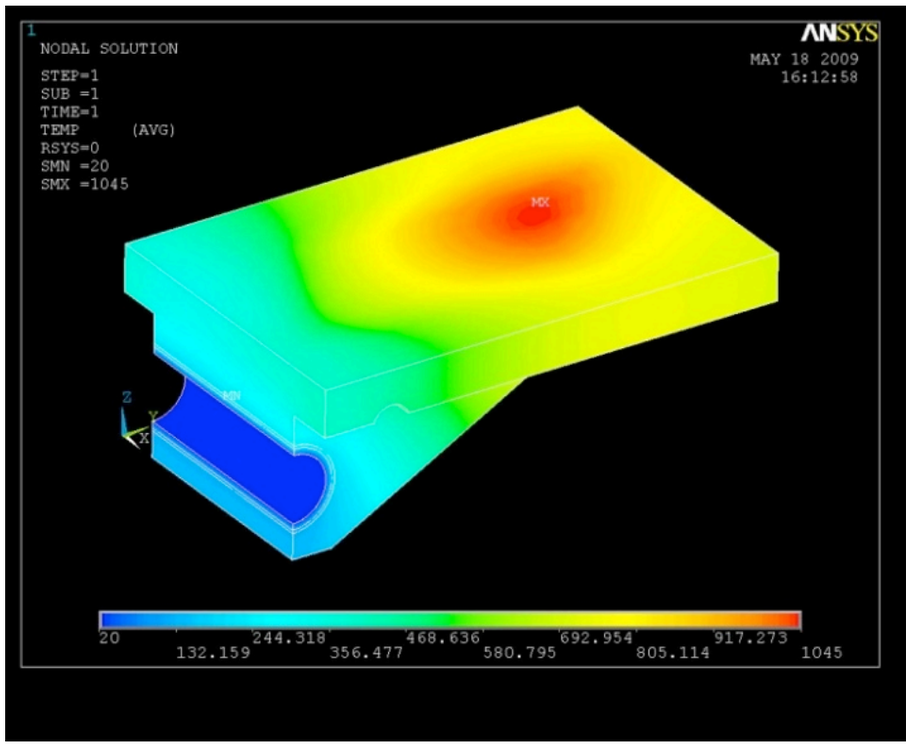


upper view

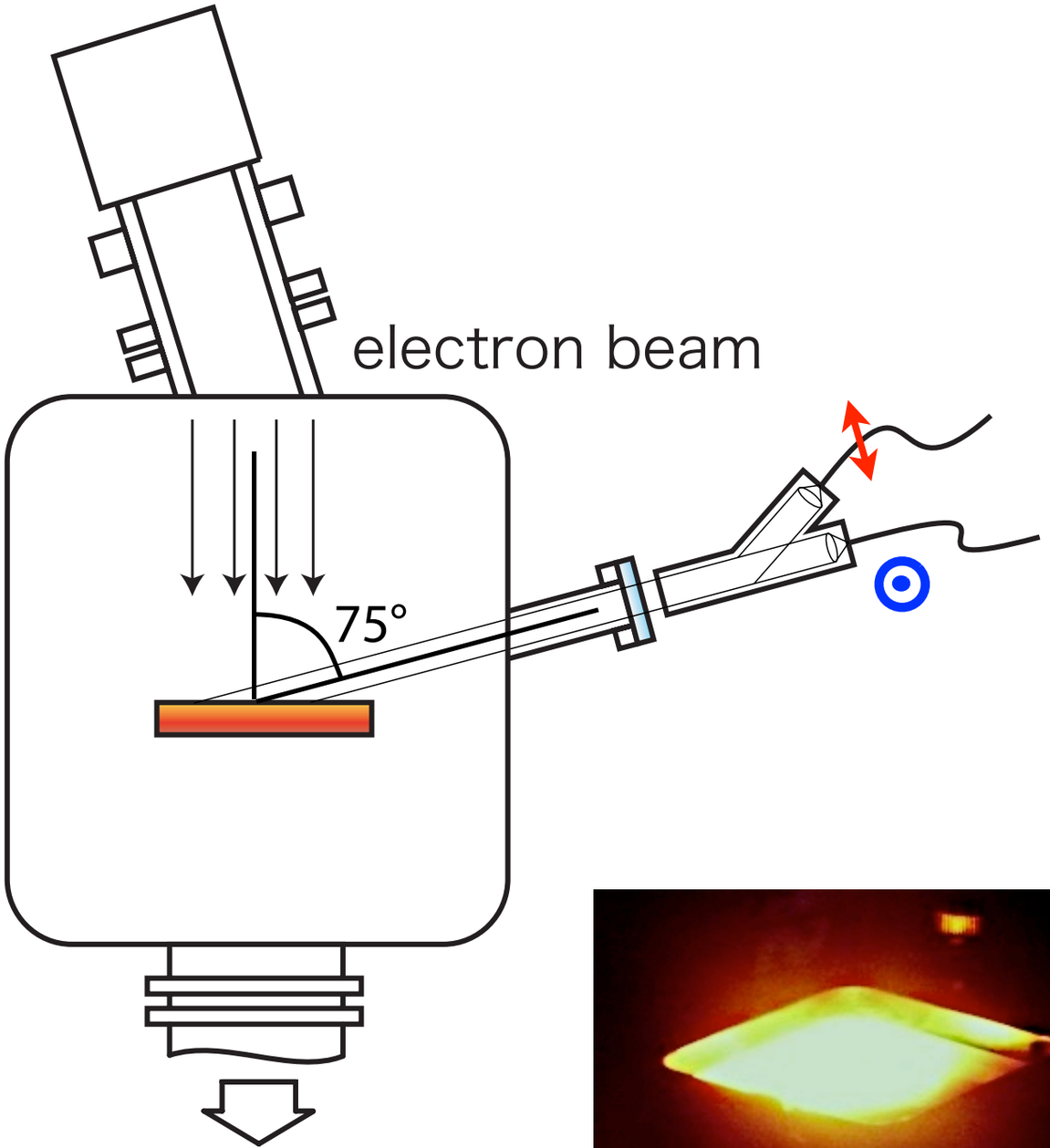


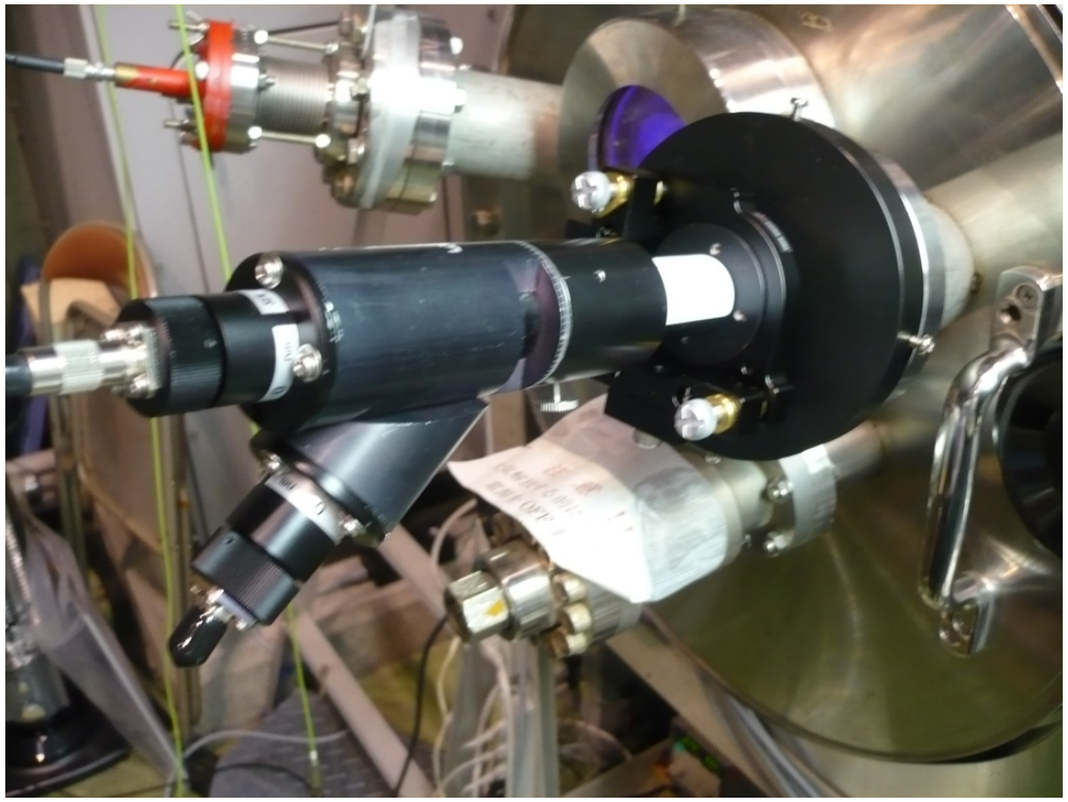
cross section





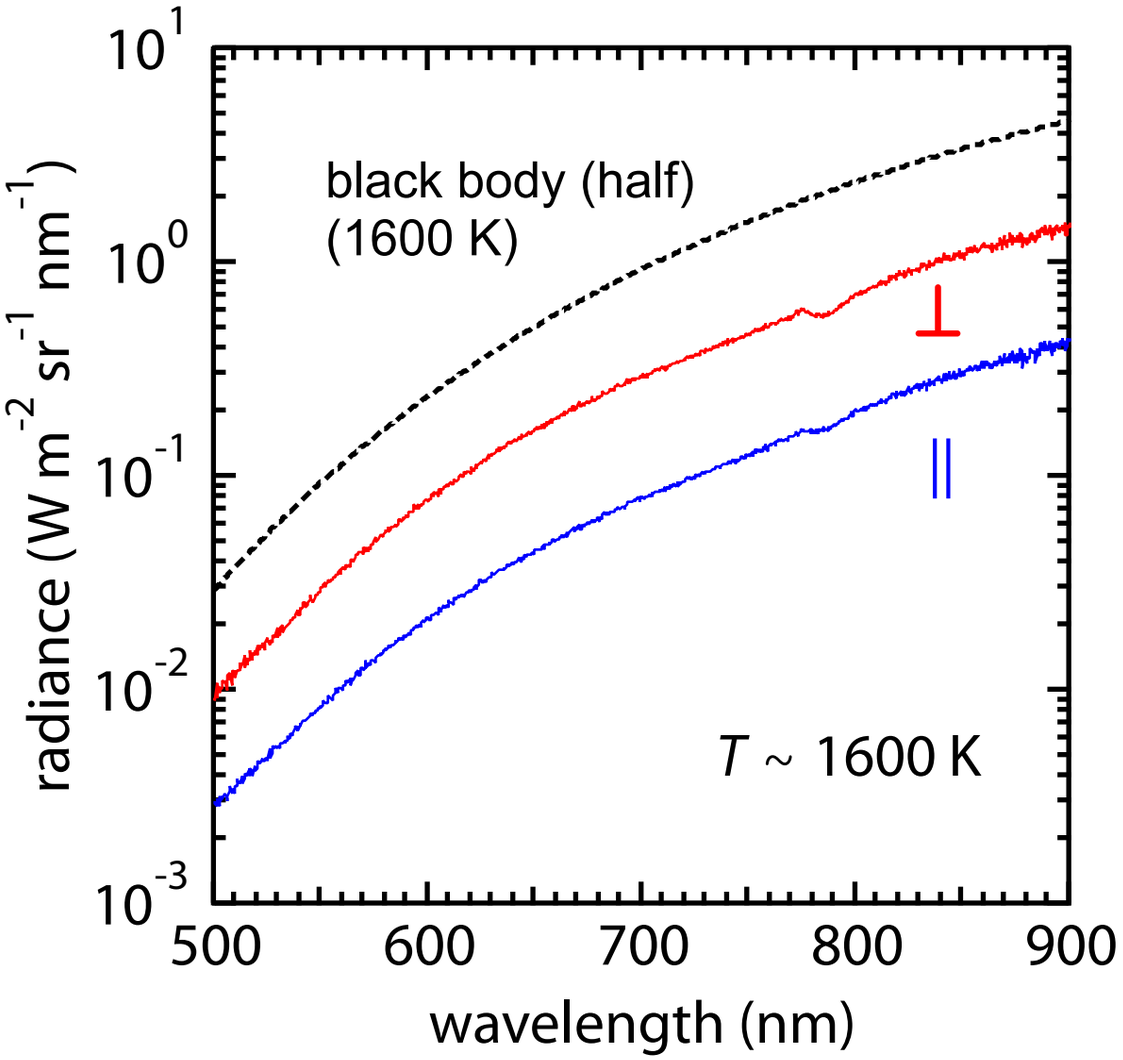
thermal radiation measurement

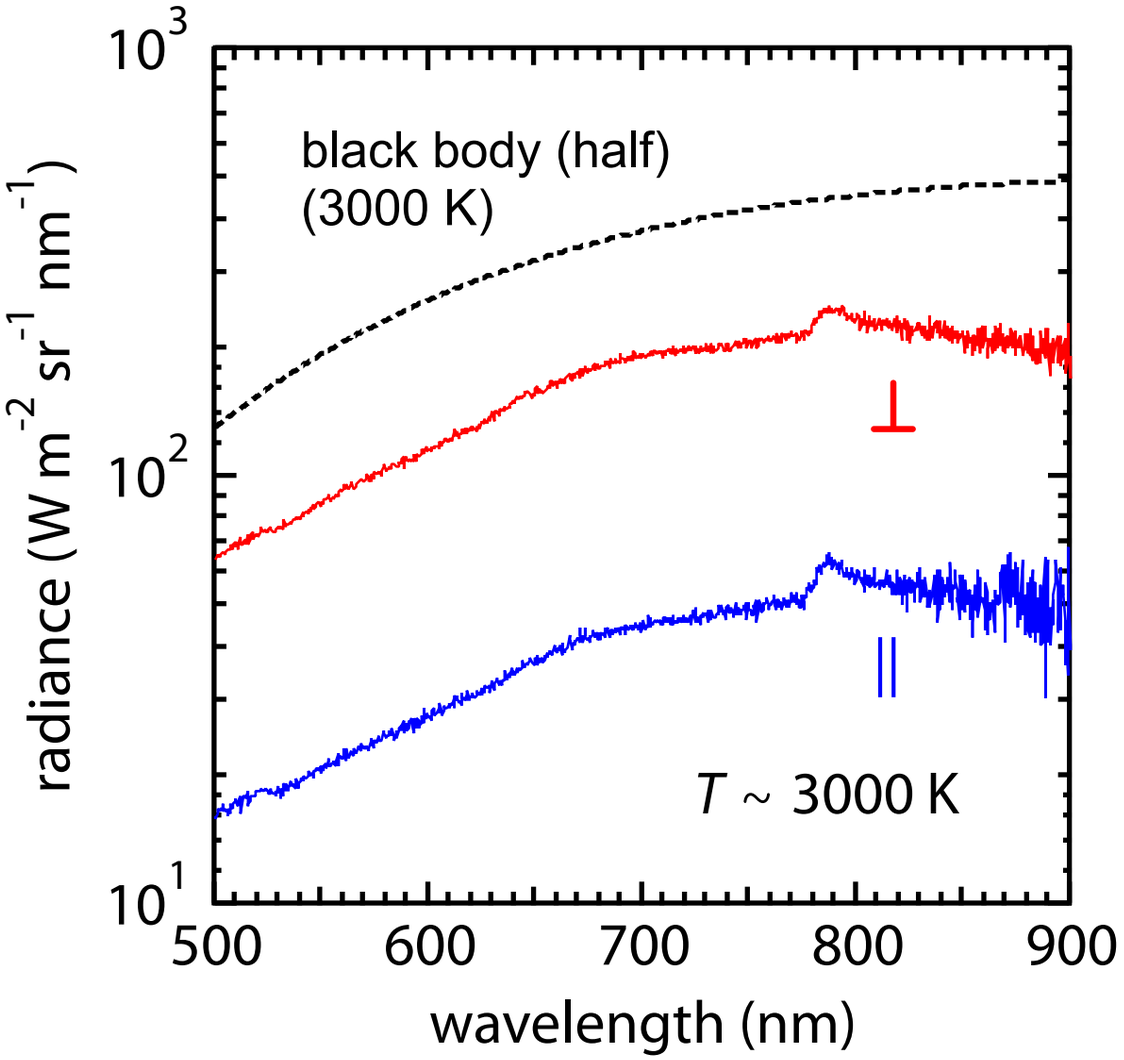




polarization resolved measurement

polarizability dependence of thermal radiation

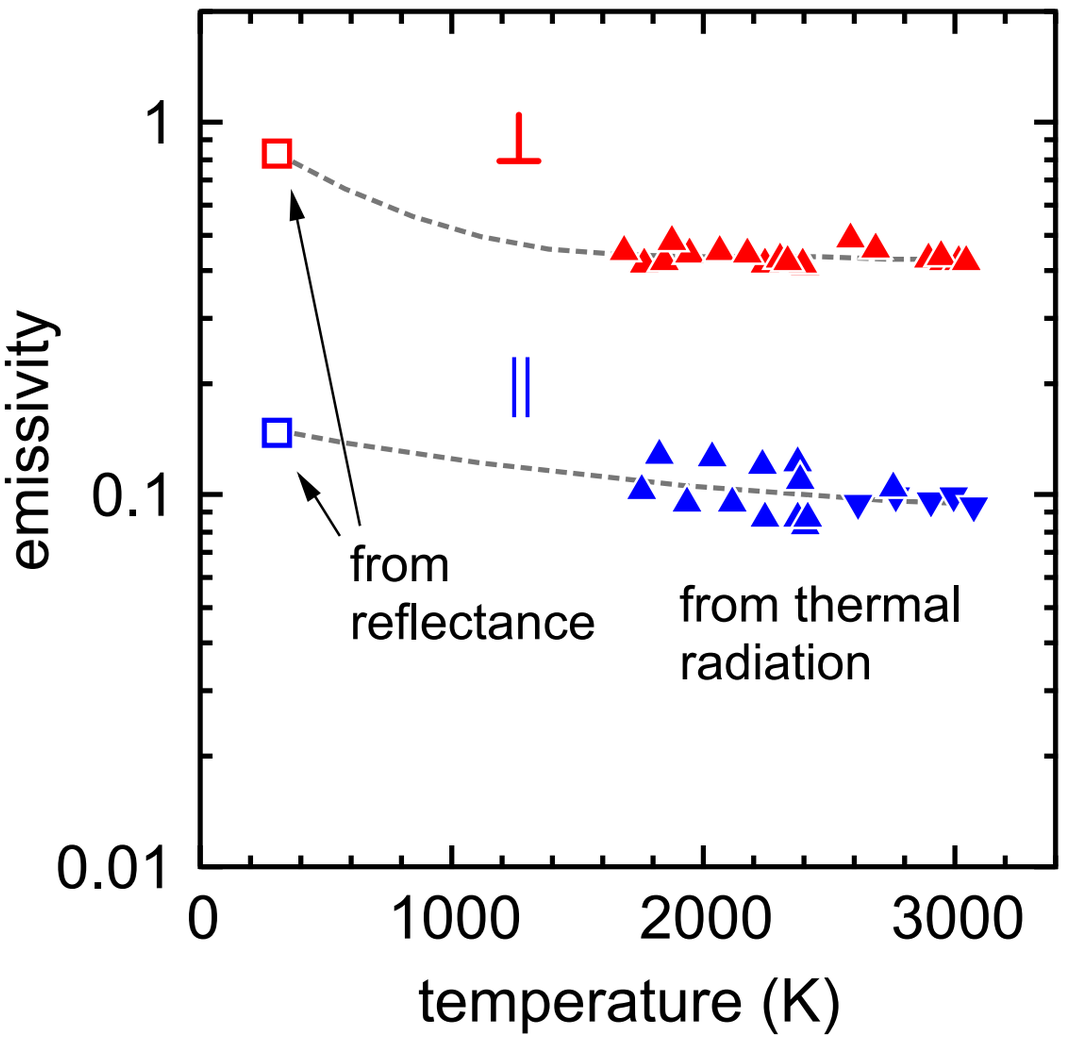


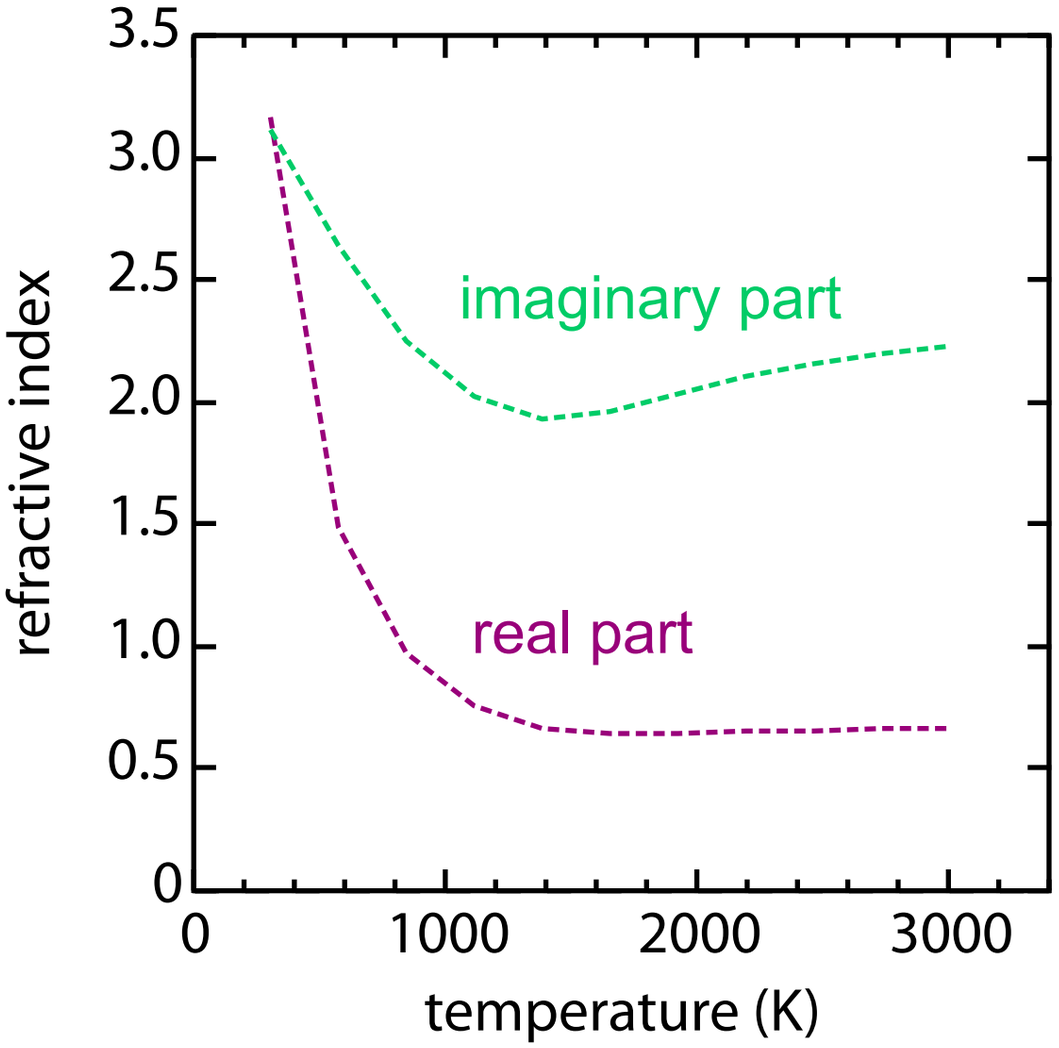


temperature and emissivity are simultaneously determined from fitting of measured spectrum

(constant λ dependence is assumed)

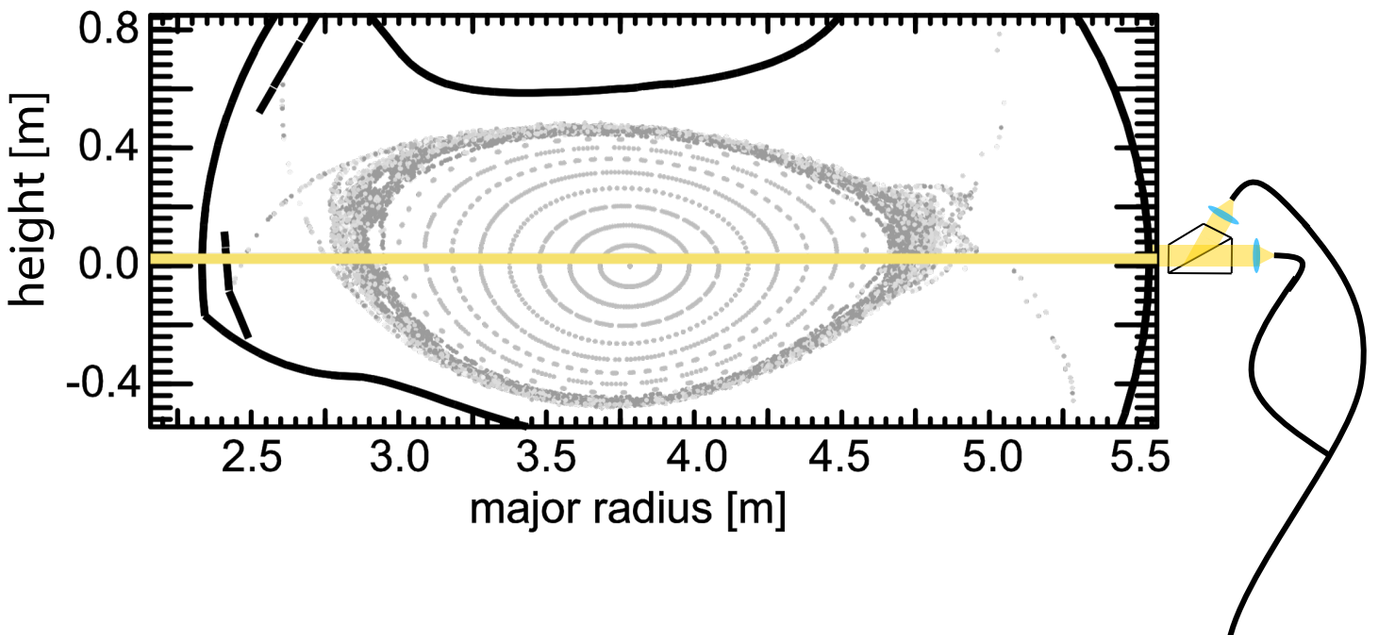
emissivity and refractive index



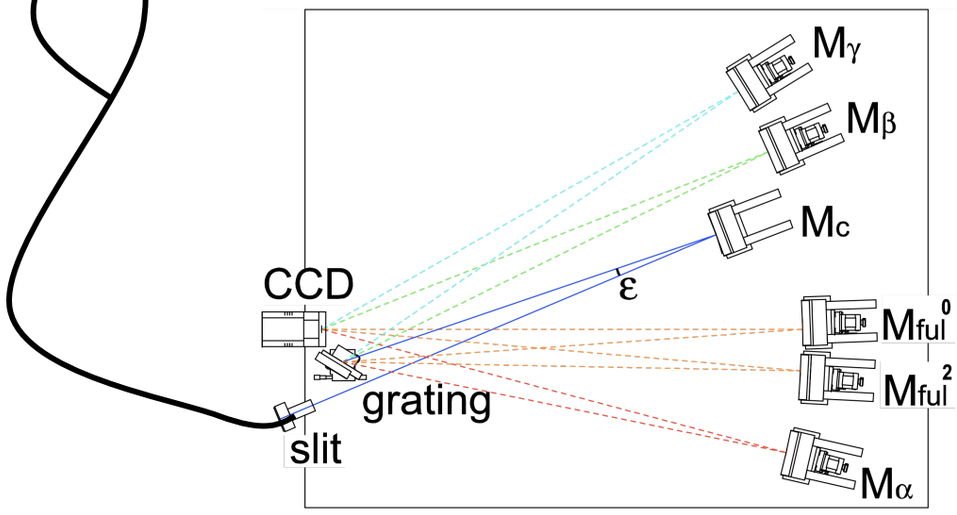


- polarized thermal radiation is clearly observed
- refractive index is derived from emissivity and Kirchhoff's law
- independent temperature measurement is required

emission location measurement



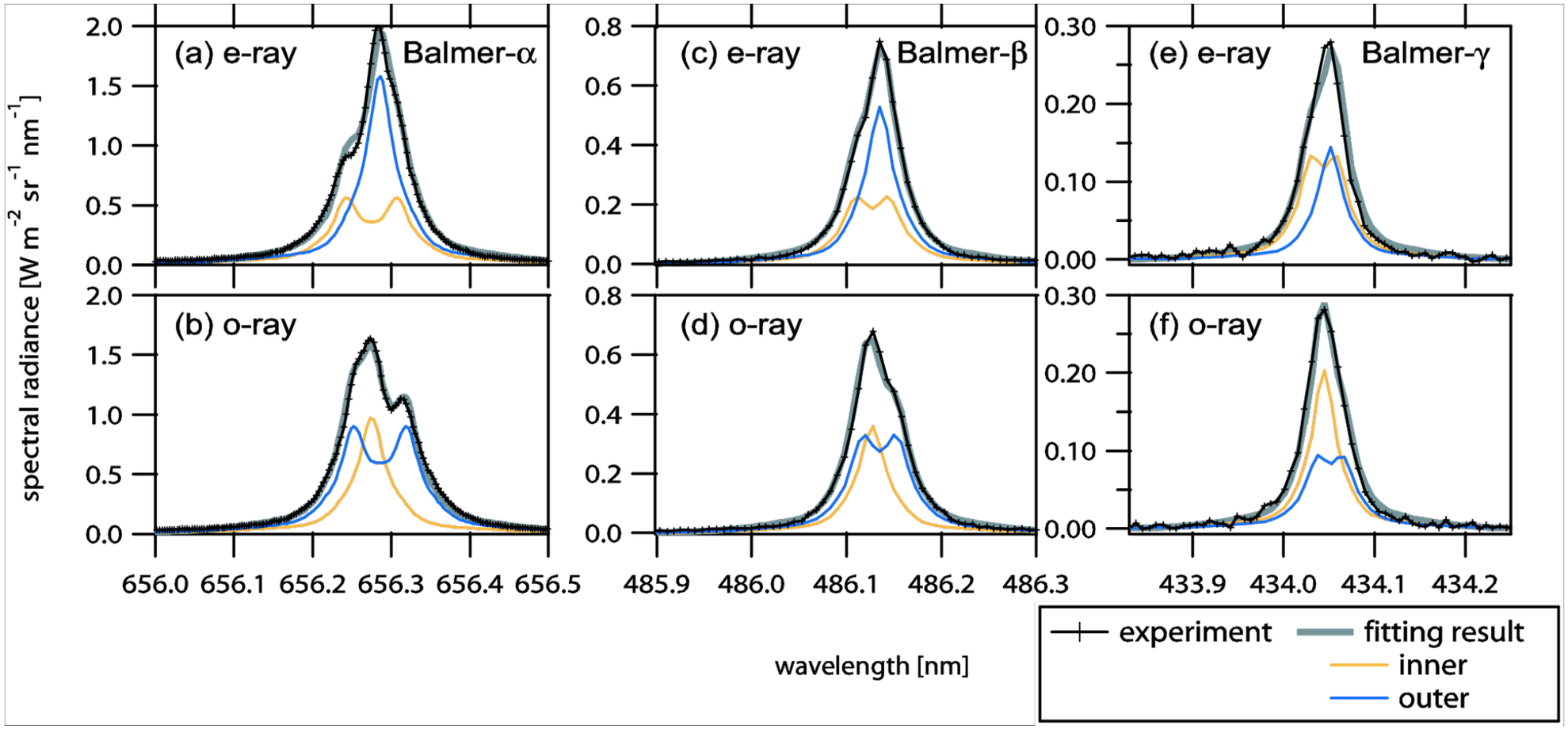
multiwavelength-range fine-resolution spectrometer

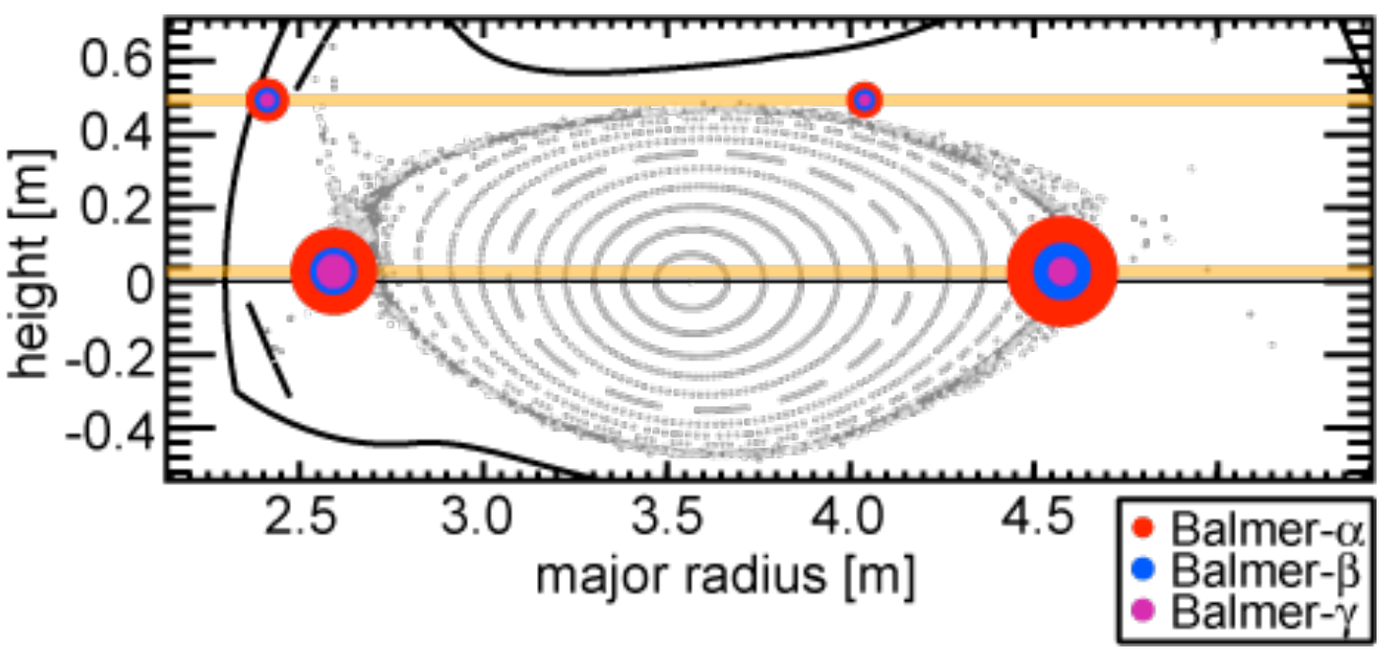


polarization resolved Zeeman spectrum is measured for Balmer α, β, and γ lines, simultanesouly

profile → emission location

intensities → plasma parameters (T_e, n_e)





emission location is determined with accuracy

parameter measurement is under way